2007

Spatial and Temporal Relationships of Adult Male Black Bears to Roads in Northwest Montana, 2003-2004

Tonya Chilton-Radandt
The University of Montana

SPATIAL AND TEMPORAL RELATIONSHIPS OF ADULT MALE BLACK BEARS TO ROADS IN NORTHWEST MONTANA 2003-2004

By

Tonya Chilton-Radandt

B.S., University of Montana, 1997

Thesis

Presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Wildlife Biology

The University of Montana
Missoula, MT

Autumn 2006

Approved by:

Dr. David A. Strobel, Dean
Graduate School

Dr. Elizabeth Crone, Chair
Wildlife Biology

Dr. Richard Mace
Faculty Affiliate

Dr. Donald Christian
The University of Wisconsin – Eau Claire

Dr. Daniel Pletscher
Wildlife Biology

Dr. Christopher Servheen
Wildlife Biology

Chilton-Radandt, Tonya. M.S., Autumn 2006

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Chairperson: Dr. Elizabeth Crone

Roads have direct and indirect consequences for wildlife. Vehicle collisions are a direct cost of roads on wildlife. Indirectly, roads may increase mortality of game species by increasing hunting pressure along these roads. Adult male black bears *(Ursus americanus)* are the most desirable age and sex class to many hunters, which may lead to over-harvest of this sex and age class. Road closures (permanently closing or seasonally restricting roads) are used to mitigate impacts of roads on wildlife, including bears. Little is known about how roads affect harvest vulnerability of black bears.

I hypothesized that adult male black bears will avoid roads during hunting seasons compared to summer; so road use, and therefore hunting vulnerability, should decrease during hunting times. I used samples of six and ten adult male black bears and evaluated the amount to which these bears avoided roads between seasons. I used ANCOVA to find the effects of season, diel period, and factor interactions on the proportion of bear locations inside a roaded area, the average road density near bear locations, and the average proportion of movements with road crossings. ANCOVA allowed me to account for the confounding of roads and elevation within my study area.

Bear distribution proximate to roads differed significantly ($p<0.01$) between seasons. Specifically, road use - especially of open roads - decreased from nonhunting to hunting seasons for both samples. Bears avoided roads during the fall compared to summer, which may reduce bear vulnerability during the fall hunt. My research neither fully refuted nor supported the question of whether restricting roads appeared to change the effects of season. Although other possible explanations exist, adult male black bears were less likely to be in the roaded area at times when shooting was legal (during the hunting seasons), which is consistent with the idea that they survive to maturity by avoiding the roaded area thus avoiding hunting and traffic.

ACKNOWLEDGEMENTS

I would like to acknowledge Montana Fish, Wildlife & Parks, without whose support I would not have had this opportunity. The MFWP employees who helped trap bears and offer advice are too numerous to mention, but I sincerely thank them all. A number of other agencies contributed to this effort, including Plum Creek Timber Company (PCTC), the U.S. Forest Service (Flathead Forest), Brown Bear Resources, and the Confederated Salish and Kootenai Tribes (CSKT); I give special thanks to Henning Stabins of PCTC and Stacy Courville and Art Soukela of CSKT. Thank you to my committee members, Drs. Elizabeth Crone, Rick Mace, Don Christian, Chris Servheen, and Dan Pletscher. I am grateful for their patience and insight. Landowners contributed greatly to this effort, including citizens of the Swan Valley and members of the Swan Ecosystem Center. In particular, I would like to thank Pat O'Herren, Sue Stanley, Russ Abolt, and Charles Brown. I appreciate Jim and Lyn Bienvenue's interest in this research. For their sage wisdom and assistance collecting bear collars, I am especially grateful to: Tabitha Graves, Karin McCoy, Nyeema Harris, and many more UM graduate students and faculty. Dave Hoerner was my only pilot for this adventure, and I would ask for no others. My greatest appreciation goes to my family, whose support I felt from 1000 miles away. Tom and Gracie, you always gave more than I expected. You helped to inspire and motivate me; thank you so very much.

Chilton-Radandt, T., M.Sc., Autumn 2006 Wildlife Biology

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INTRODUCTION

Roads can have direct and indirect consequences on wildlife. Vehicle collisions are the most pervasive direct risks facing wildlife. Indirectly, roads may increase mortality of game species by increasing hunting pressure along these roads. The effects of roads on hunting vulnerability of species such as white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elephus*) have been widely studied (Sage et al. 1983, Unsworth et al. 1998, Gratson and Whitman 2000, McCorquodale et al. 2003). Sage et al. (1983) found a significant correlation between roads and the amount of observable white-tailed deer; higher road densities correlated with higher deer observation rates. Research by McCorquodale et al. (2003) examined road variables important to increases in hunting vulnerability, showing that elk mortality rose with increasing road densities.

Montana's game managers have observed that many black bear *(Ursus americanus)* hunters in Montana hunt along open roads, and these hunters are more successful than those who do not use roads (Montana Fish, Wildl. & Parks, unpubl. data). As with many other big game species, adult male black bears are the most desirable age and sex class (Bunnell and Tait 1980) because of their large size and trophy status (McIlroy 1972; Montana Fish, Wildl. & Parks, unpubl. data). This may cause hunters to harvest a disproportionate number of mature male black bears and potentially lead to over-harvest of adult males (Bunnell and Tait 1980).

Adult male black bears could be particularly more susceptible to hunting than female or younger male bears due to behavioral differences. Adult male black bears spend more time outside their dens; they are the first to leave dens in the spring and travel more during the spring mating (and hunting) season than females and other age classes (McIlroy 1972, Kolenosky 1986, Rogers 1987, Kohlman et al. 1999, Noyce and Garshelis 1997). Females and young males also return to dens in the fall sooner than mature males, exposing older male black bears to greater harvest pressure in the fall season. It is illegal to harvest a female with cub(s), which also decreases harvest pressure on females with cubs relative to males (Bunnell and Tait 1980). For these reasons, hunting vulnerability of adult male black bears may be greater than that of females and other age classes.

Little is known about how roads may affect harvest vulnerability of bears (Litvaitus and Kane 1994, Mace et al. 1996, Kohlmann et al. 1999), especially black bears (Montana Fish, Wildl. & Parks, unpubl. data). Adult males in Montana may avoid roaded areas more than other sex and age classes. Mace et al. (Montana Fish, Wildl. & Parks, unpubl. data) reported that the proportion of subadult male bears in annual Montana Fish, Wildlife & Parks (MFWP) regional harvests increased with road density. Some researchers (Montana Fish, Wildl. & Parks, unpubl. data; Rogers 1987) have suggested that these data may result from adult males displacing subadults to areas closer to roads, rather than a population with more subadults overall. Regardless, the relationship between bear vulnerability and hunter access into bear habitat via forest roads warrants further study.

Few studies have evaluated the impact of road closures (permanently closing or seasonally restricting roads) on wildlife (Joslin and Youmans 1999, Gratson and Whitman 2000), including bears (Mace et al. 1996, Stabins et al. 2001, Wielgus and Vernier 2003). Road closures are used in part to mitigate negative impacts of roads on wildlife such as bears (Mace et al. 1996, Puchlerz 1995). In addition to vehicle collisions and increased hunting mortality, roads can impact bears through disturbance at den sites (Lindzey and Meslow 1977, Tietje and Ruff 1980) and habituation to humans (Gunther 1994). By restricting vehicle access on roads, land managers hope to minimize these issues.

In this study, I use GPS location data to evaluate how adult male black bears change habitat use relative to roads between hunting and nonhunting times (legal hunting seasons and legal shooting hours). I test whether habitat use by bears in roaded areas differs between hunting and nonhunting times. I assess whether bear habitat use changes during times when bears are most vulnerable and determine whether habitat use changes as a function of restricting vehicle access on roads (“road restriction,” including gating, berming, and reseeding of roads). Specifically, I evaluate bear use of a roaded area in times when bears are vulnerable versus times when they are not, calculate road densities proximate to bears for open and restricted roads during hunting and nonhunting times, and examine bear road crossings of open and restricted roads during hunting versus nonhunting times**.**

Study Area

The 805 km^2 Swan Valley in western Montana is a relatively flat, glacier-scoured valley that lies between the Mission and Swan Mountain ranges (Fig. 1) and extends from the Swan-Clearwater hydrologic divide in the south to Swan Lake in the north end. The valley is bordered by wilderness areas to the west (Mission Mountains Wilderness) and east (Bob Marshall Wilderness). The majority of development, mostly in the form of residential housing, occurs along State Highway 83, which runs north-south and bisects the valley.

Elevations in the Swan Valley vary from 935 m on the valley floor to over 2500 m on mountain peaks. Swan Valley habitat types (Pfister et al. 1977) include Spruce/Queen’s cup (*Picea spp./Clintonia uniflora*) and Hemlock/Queen’s cup (*Thuja plicata/Clintonia uniflora*) in mesic areas and Douglas-fir/Bluejoint (*Pseudotsuga menziesii/Calamagrostis rubescens*) and Grand fir/Queen’s cup (*Abies grandis/Clintonia uniflora*) at higher elevations (Mundinger 1980). Riparian communities are numerous in the valley, and rocky outcrops and shrub fields define the mountaintops.

A checkerboard of land ownerships, including public, private residential, and private industrial lands, characterizes the study area. Timber harvest is the primary land use on private industrial lands (Mundinger 1980); much of the valley is roaded. Most roads are open to public travel, although some are gated, bermed, or are otherwise restricted to use. Primary public land uses include hiking, berry-picking, pleasure-driving, and firewood-cutting (D. Hobbs pers. comm.). Free-range cattle grazing leases occur occasionally only in the southern half of the valley.

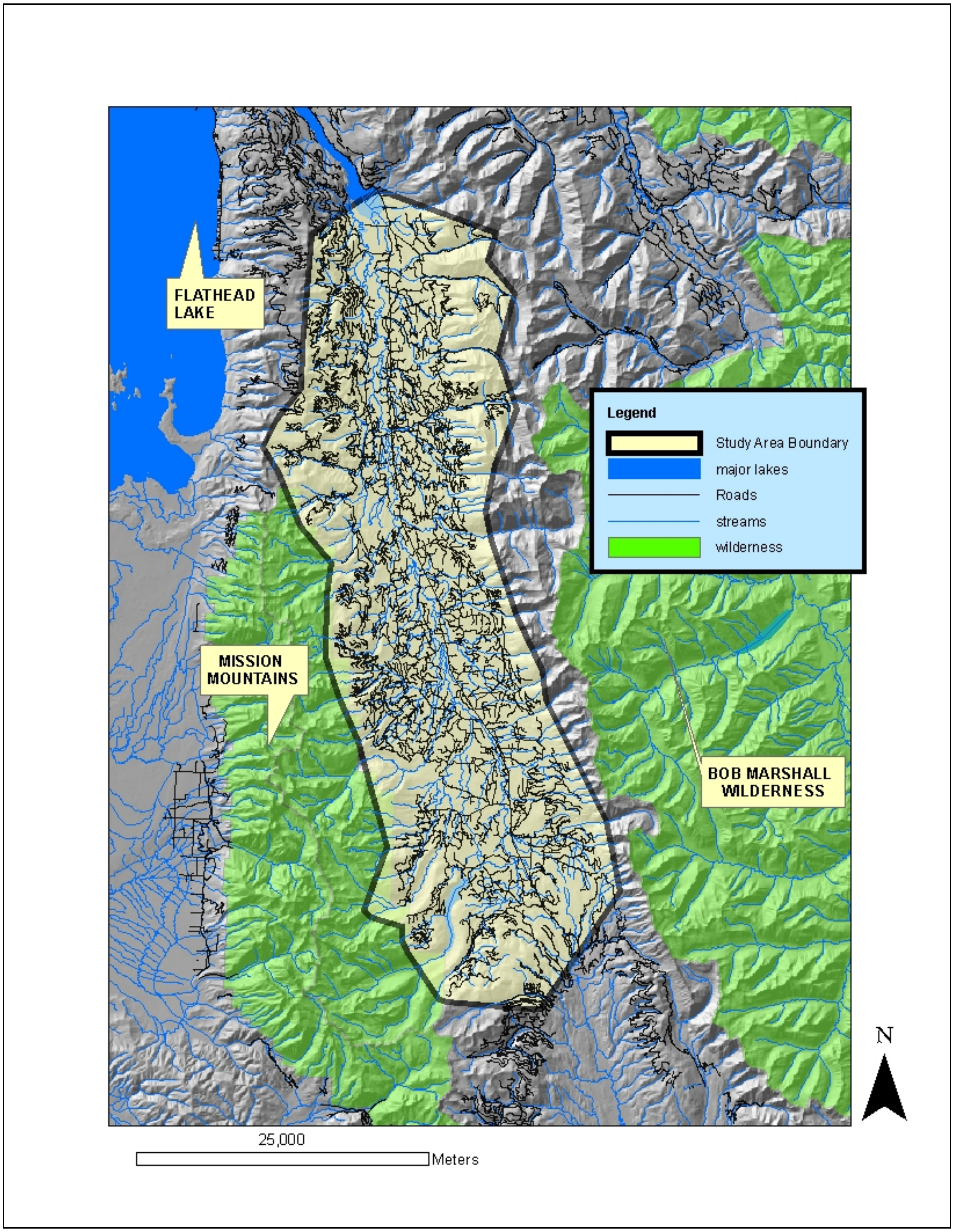


Figure 1. Swan Valley study area of northwest Montana, including roaded area boundary and wilderness areas. 2003-04.

Annual average snowfall is 338 cm and average monthly temperatures vary between –1 and +15^{o} C (The Western Regional Climate Center). Average annual precipitation totals 73 cm.

METHODS

Defining the Roaded Area

I used the distribution of roads in the Swan Valley to approximate the study area ("roaded area"). To delineate the roaded area, I used GIS layers of United States Forest Service (USFS) wilderness areas and Plum Creek Timber Company (PCTC) road maps. In ArcView 3.3 (Environmental Systems Research Institute, Olympia, WA, USA), I buffered the outermost roads (roads nearest wilderness) by approximately 500 m. An distance of 500 m roughly defined the end of most roads and the beginning of wilderness, or non-roaded, areas in the Swan Valley. In this way, most wilderness was excluded from the roaded area for ANCOVA analyses.

Capture and Telemetry

Black bears were captured using Aldrich leg-hold snares and handled per the guidelines of Jonkel (1993). Bears' ages were estimated in the field using standard teeth wear techniques (Jonkel 1993), and a tooth was pulled and sent to a lab for accurate aging (Willey 1974; Mattsons Lab, Milltown, Montana, USA). Attempts to capture bears began in April each year and extended through June, so collared bears' movements would include Montana's spring hunt season. Trap site locations were chosen to encourage random sampling within the roaded area. For safety reasons, all trap sites were located within 150 m from roads (as per MFWP protocol). To prevent potential hunter bias against tagged bears in this hunting district, small, dark ear-tags and dark collar belting were used.

I radio-instrumented 15 adult male black bears with Telonics (Mesa, Arizona, USA) Generation-3 model 3600 GPS collars between 2003 and 2004. GPS collars were programmed to obtain locations once every 2 h and store these locations on-board the unit. The collar unit was programmed to fall off 5

October, a date prior to the average denning date of black bears in this area (Montana Fish, Wildl. & Parks, unpubl. data), but late enough to include a portion of Montana's fall hunt season.

GPS collar locations were accurate to within 100 m (Telonics, Mesa, Arizona, USA). These locations were not differentially corrected (a process using base stations located near the study site to improve average accuracy of locations to within 3-5 m). Locations were converted from latitude/longitude to UTM units.

I used both 2-dimensional (2D) and 3-dimensional (3D) location fixes (satellite downloads) to determine collar "fix success" (percent successful downloads of bear locations from the satellites to the collar). The 3D fix was the most accurate and involved triangulation of 4 or more satellites to acquire a GPS collar location. Alternatively, 2D signals were calculated if 2 or 3 satellites were available. If fewer than 2 satellites were available, no location was fixed. I determined collar "fix success" by dividing the number of successful satellite fixes by the total number of fixes attempted.

Of 11 GPS collars that worked successfully, 4 bears' collars had data in the roaded area only during the summer season, 6 bears' collars had locations in the roaded area in summer and fall hunt seasons, and 2 bears' collars had data from inside the roaded area which included spring hunt, summer, and fall hunt seasons.

GIS Road Map Validation and Classification

A composite map of forest roads across land ownerships had been built by PCTC in 2003. Given preliminary fieldwork, this composite map was found to be the most accurate road map available for the study area, although it was not without error. I assessed the degree of error in the GIS road map in the field by visiting a sample of road segments. I documented accuracy of location, identified and mapped any roads absent from the map, and determined current road closure status. I used ArcView (Environmental Systems Research Institute, Olympia, WA, USA) for all GIS analyses.

Using the most updated PCTC road closure maps available each year, I categorized roads as either open to traffic or "restricted." "Restricted" roads were defined as closed to motorized vehicle traffic and included gated, revegetated and bermed roads (Puchlerz 1995).

Traffic Volume Data Collection and Assessment

I evaluated road counter data from 20 USFS road counters between 2003-04. These pneumatic counters (Diamond Traffic Products, Oakridge, OR, USA) had been placed in the southern half of the Swan Valley, within the home ranges of the GPS-collared bears. USFS employees collected the counter data from the field at the end of each month and compiled monthly traffic counts. Data were not collected during every month for either year; this means that some season count averages include only limited months within that season (e.g., the average count for spring hunt may include only April, rather than April and May). I assessed these data and compiled them into seasonal averages.

I compiled monthly traffic counts into seasonal daily averages by dividing their monthly sums by the total number of days in each season. Traffic counter dates were not always equivalent to my defined seasons; although my spring hunt season was restricted to the hunting season dates of 15 April – 30 May, the traffic counter data were collected over the entirety of each month. This said, to determine my spring hunt average, I assigned all traffic counter data taken during April to the spring hunt average, using 30 days in April rather than just 15 days, and summed the days within each entire month.

Defining Seasons and Diel Periods

I classified seasons as “spring hunt,” “summer,” and “fall hunt.” Spring hunt and fall hunt seasons were defined by the state-regulated hunting seasons each year (April 15 – May 30, and September 1 – end November, respectively). The date marking the end of the fall hunting season occurred on the Sunday following Thanksgiving every year, so the exact date marking the end of the hunting season varied between years. Summer was defined as 1 June to 31 August.

I also stratified telemetry data by diel period. Using seasonal sunset and sunrise tables (U.S. Naval Observatory, Astronomical Applications), I partitioned each 24 h period into "day," "night," and "crepuscular". The length of day and night hours varied due to changing amounts of sunlight. To ensure full light and darkness in each day and night diel period, I defined "day" as 1 h after sunrise until 1 h before sunset, and defined "night" as the period between 1 h after sunset and one hour before sunrise. I defined a "crepuscular" location as a bear location within the 2 h window defining sunrise (complete light) and sunset (complete darkness) (Garshelis and Pelton 1980, Nielsen 1983, and Gaines and Lyons 2003).

Differences in Seasonal Effects between Road Types

I qualitatively compared average values of open and restricted roads, which allowed me to evaluate whether bears responded differently to each road type. If bears responded differently across seasons to restricted roads than to open roads, the direction and magnitude of the effects would differ between road types (e.g., if bear distribution proximate to open roads decreased from summer to fall hunt, and bear distribution proximate to restricted roads across the same seasons increased, then bears' were responding differently to each road type).

Study Design

I restricted most analyses to bear locations within a roaded area to help discriminate between the confounded factors of elevation and roads. As such, I examined bears' habitat use within the roaded area, on both large (ANCOVA #1) and smaller scales (ANCOVAs #2-3). Not all bears confined their movements to the roaded area; a small sample of the bears collared for this study used wilderness areas more than areas near roads (Appendix).

ANCOVA allowed me to compare habitat use among seasons and diel periods, while accounting for the confounding of roads and elevations in this landscape. The use of ANCOVA (rather than ANOVA) gave me a description of the amount of variation that is explained by elevation. Another advantage of ANCOVA is that statistically significant differences of each factor included in the models could be determined.

I used an alpha-level of 0.15, larger than the standard significance level, because of my small sample sizes. While my small sample sizes justify a greater alpha-level of 0.15 (Field et al. 2004), more conservative wildlife managers might select a smaller alpha level.

To account for the fact that the data included multiple observations per bear, and that each bear could differ in habitat use, I used a mixed model ANCOVA. I evaluated the effect of season, diel period, and factor interactions (the independent variables) on road metrics (dependent variables) relative to bears' locations. I determined the mean and upper and lower confidence intervals of associated road metrics, and compared these statistics within factors (e.g., comparing summer to fall hunt or day to night diel periods).

Proportional Habitat Use between Seasons: ANCOVA #1. To determine how adult male black bears distribute themselves within and outside of roaded areas, I first examined large scale trends in the study area. For this large scale analysis, I identified whether bear distribution changed relative to roads during hunting times and nonhunting times.

I used 10 bears whose collar data included summer and fall hunt seasons and locations from both inside and outside the roaded area. I censored bear #299 because this was the only bear whose location data included only one season (summer) and did not leave the roaded area. I compared the average proportion of bear locations in the roaded area between seasons and among diel periods and factor interactions. I used a mixed logistic model on these proportional data, with elevation as my covariate (lmer function in R; Free Software Foundation, Inc., Boston, MA, USA). I ln-transformed values prior to analysis, and found average values and any significant factors for this model. I used the slope coefficient of elevation to determine the magnitude and direction of elevation effects.

Average Road Type Densities between Hunting and Nonhunting Times: ANCOVA #2. This analysis described habitat use for bears that stayed inside the roaded area during the fall hunt. I evaluated road density relative to bear locations to investigate habitat use on a finer scale than in the first analysis.

I tested the null hypothesis of no difference in road density proximate to bear locations among hunting and nonhunting times. I calculated the density of open and restricted roads relative to each bear location, as a function of season and diel period, as well as interactions thereof. I used 6 bears whose collars had locations in the roaded area in both summer and fall hunt seasons. Within the roaded area, I calculated road density proximate to these 6 bears by dividing length (km) of road by buffer area (km/km^2, Mace and Waller 1997). I buffered each bear location with a circular buffer whose diameter equaled the average total movement length in a 2 h period, respective to each bear. I calculated road densities of both open and restricted roads within the movement buffer, for every bear location. As these data were not normally distributed, I ln-transformed road densities prior to analysis. I used the slope coefficient of elevation to determine the magnitude and direction of elevation effects.

Average Proportion of Crossings of Different Road Types between Hunting and Nonhunting Times: ANCOVA #3. For a second, finer-scale analysis, I compared the proportion of movements that crossed a road, among seasons, diel periods, and interactions thereof. This analysis also described habitat use by bears that used the roaded area during the fall hunt. I used 6 bears whose collars had locations in the roaded area in both summer and fall hunt seasons, and calculated the proportion of movements that crossed a road of each type, per bear, as a function of season and diel period. Using Animal Movement extension (SA v 2.04 beta, USGS-BRD, Alaska Science Center Biological Office, Glacier Bay Field Station, USA), I sequentially connected bear locations in the roaded area to form movement paths. Only 2 h successive points were used in this analysis; lone points and points at >2 h intervals were not included. After buffering each road by the largest GPS collar error (100 m), I used Alternate Animal Movement Routes extension (Alternate Animal Movement Routes v. 2.1, Jeff Jenness, Jenness Enterprises, USA) to determine the number of movements in each season and diel period that crossed both open and restricted roads. I evaluated the proportion of movements that crossed an open road and repeated the analysis for restricted roads. As these proportional data were not normally distributed, I transformed them using the arcsine-squareroot transformation. I used the slope coefficient of elevation to determine the magnitude and direction of elevation effects.

RESULTS

Captures

Eight adult male black bears were captured in 2003 and 7 bears in 2004 (Table 1). The mean age of these bears was 9 years. One of the 15 total captured bears was a recapture from 2003; 2 black bears were recaptures from a previous MFWP black bear study in the Swan Valley. These 15 adult male black bears were monitored during a total of 3 seasons in each of 2 years. Eleven of the 15 total GPS collars contained data that I could successfully retrieve; 3 of the 4 remaining bears' collars malfunctioned, and one disappeared. Among this sample of GPS collared bears, fix success for combined 2-D and 3-D fix types averaged 69% (Table 1).

GIS Road Map Data Validation and Classification

Most (86%, $n = 191$) road segments labeled as restricted on the map were restricted and in the correct location, when validated against information collected in the field. Open roads were 93% accurate ($n = 321$). Most errors of restricted roads resulted from recent road openings, usually meant for logging operations. Most errors in the open road map resulted from recent changes from open to restricted road status.

Traffic Volume Data Collection and Assessment

During 2003 and 2004, average traffic counts along open roads were least for spring hunt season (8 vehicles/day, SD = 4.2, and 15 vehicles/day, SD = 19.8, respectively). During 2003, average traffic counts were greatest during summer (25 vehicles/day, SD = 24.4). Average traffic counts for 2003 fall hunt season equaled 22 vehicles/day (SD = 17.4). Average traffic counts for 2004 were greatest during fall hunt (21 vehicles/day, SD = 12); traffic counts for 2004 summer equaled 18 vehicles/day (SD = 16.7).

Table 1. Adult male black bear (*n* = 15) capture, age, and telemetry information. Swan Valley study. 2003-04.

Black bear number	Capture date	Age (years)	Radio days	Total number successful fixes attempted	Total number successful fixes	Fix success (%)
104[a]	5/18/03	14	140	1683	1285	76
105[a,b]	5/19/03	14	139	1671	1179	73
109[a]	6/4/03	10[c]	123	1480	997	67
113[a,b]	6/6/03	10	121	1453	1034	71
117[a]	6/8/03	8	120	1433	1054	74
119[a]	6/12/03	5	115	1382	907	66
120[a,b]	6/13/03	7	115	1380	1016	74
299	6/7/03	5	55	651	377	58
5[a,b]	4/28/04	9	160	1923	1476	77
28	4/23/04	10[c]	d	d	d	d
32[a,b]	5/18/04	12	143	1678	630	38
117	5/18/04	10	d	d	d	d
182	5/15/04	6	d	d	d	d
185	5/13/04	5[c]	d	d	d	d
192[a,b]	5/27/04	9	1984	1984	1569	79
Mean	---	9	127	1520	1048	69
SD	---	5	29	355	350	11

a = Individuals used for ANCOVA #1.
b = Individuals used for ANCOVA #2 and #3.
c = Estimated age. Tooth not collected, or, if tooth collected, lab was unable to process for age.
d = Collar malfunctioned or is missing.

ANCOVA

Proportional Habitat Use between Seasons. For 10 bears, after the effects of elevation were removed, the average proportion of locations in the roaded area varied significantly by season (mixed logistic model, $p < 0.01$, Table 2), diel period ("diel", $p = 0.01$), and elevation ($p < 0.01$).

Table 2. Proportion of locations in the roaded area across seasons and diel periods ("Diel"), with elevation as a covariate. Swan Valley, Montana. 2003-04.

Effect	df	Chi-square	p
Bear number	1	1152.0	<0.01
Season	1	423.5	<0.01
Elevation	1	19389.0	0.01
Diel	2	9.1	<0.01
Bear*season	1	664.0	0.33
Bear*diel	2	12.7	0.28
Season*diel	2	2.2	0.33
Bear*season*diel	2	2.5	0.28

The proportion of time that bears spent in the roaded area decreased from 0.75 (95% CI = 0.55, 0.89) during the summer season to 0.22 (95% CI = 0.02, 0.82) in the fall hunt season (Fig. 2). The proportion of points in the roaded area was greatest during day (0.73; 95% CI = 0.51, 0.88; Fig. 3), less during crepuscular times (0.71; 95% CI = 0.49, 0.87), and least during the night (0.68; 95% CI = 0.44, 0.85). The slope coefficient for elevation was –0.886.

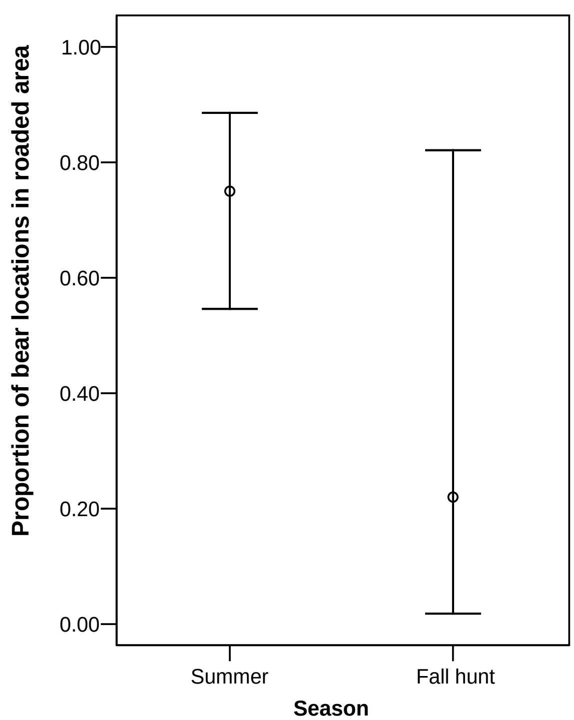


Fig. 2. Seasonal averages and 95% confidence intervals for the proportion of points in the roaded area (*n* = 10 bears). Swan Valley, Montana. 2003-04.

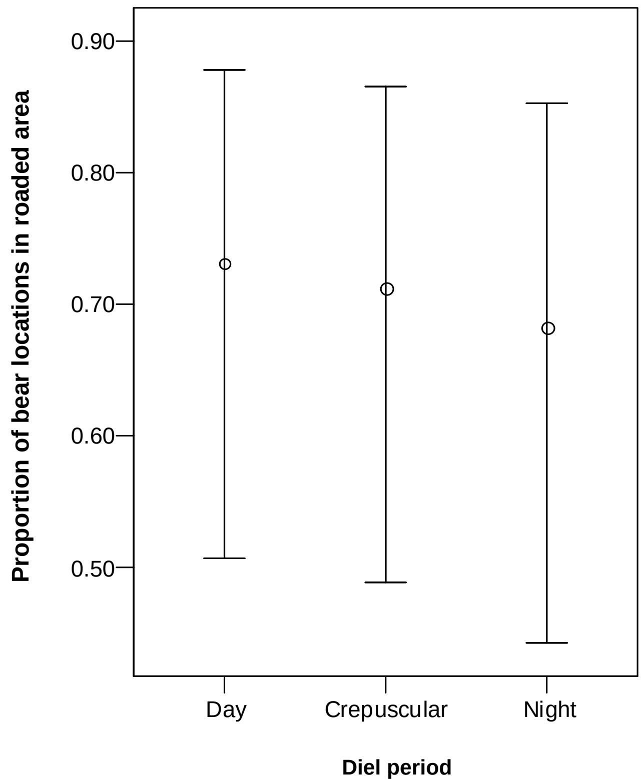


Fig. 3. Averages and 95% confidence intervals for the proportion of points in the roaded area among diel periods (*n* = 10 bears). Swan Valley, Montana. 2003-04.

Average Road Densities Near Bear Locations. Average open road density around bear locations was 0.65 km/km^2 (95% CI = 0.62, 0.69) during summer and decreased to 0.44 km/km^2 (95% CI = 0.33, 0.56) during fall hunt (Fig. 4). After accounting for the relationship between road density and elevation, adult male black bears (*n* = 6) were in areas with higher open road density during summer than during the fall hunt (p = 0.11, Table 3), although elevation explained more of the variation. Open road densities proximate to bear locations did not differ among diel periods (p = 0.51, Table 3). The slope coefficient of elevation for this analysis was –0.001. Restricted road densities proximate to these 6 bears did not change seasonally (p = 0.69) or among diel periods (p = 0.36, Table 3). Although the direction of the effect of season was similar for both open and restricted roads (Fig. 4), the magnitude of the effects of season differed between open and restricted roads.

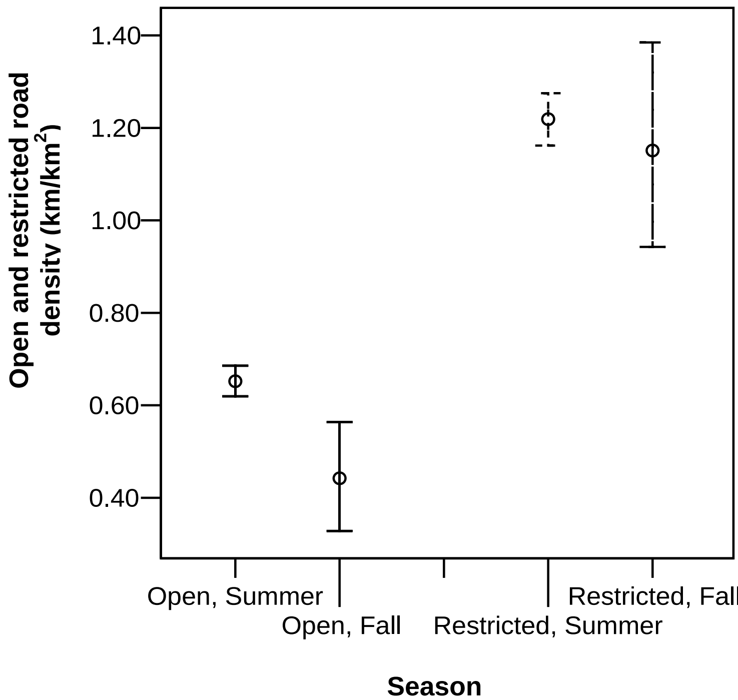


Fig. 4. Average open and restricted road density (km/km^2) and 95% confidence intervals proximate to bear locations between summer and fall hunt (“fall”) seasons (*n* = 6 bears). Swan Valley, Montana. 2003-04.

Table 3. Open and restricted road density as a function of season, diel period ("Diel"), individual bear ("Bear number"), and interactions, with elevation as a covariate. Error terms were calculated from SPSS default as described in footnotes. Swan Valley, Montana. 2003-04.

	Open roads							Restricted roads						
Effect	SS	df	Hypothesis MS	Error MS	Error df	F	p	SS	df	Hypothesis MS	Error MS	Error df	F	p
Bear number	11.8	5	2.3	1.0[a]	4.0	2.3	0.22	24.1	5	4.8	1.0[a]	4.2	4.6	0.08
Season	3.0	1	3.0	0.8[b]	6.1	3.5	0.11	0.1	1	0.1	0.8[b]	6.9	0.1	0.69
Elevation	21.2	1	21.2	0.3[c]	4470.0	70.2	<0.01	143.0	1	143.0	0.4[c]	4470.0	300.8	<0.01
Diel	0.5	2	0.2	0.3[d]	16.0	0.7	0.51	1.2	2	0.6	0.5[d]	17.2	1.1	0.36
Bear*season	5.4	5	1.1	0.4[e]	12.2	2.3	0.10	5.2	5	1.0	0.5[e]	13.1	1.8	0.16
Bear*diel	4.2	10	0.4	0.5[f]	10.0	0.8	0.60	5.7	10	0.5	0.5[f]	10.0	1.0	0.50
Season*diel	0.2	2	0.1	0.4[g]	15.1	0.2	0.76	0.5	2	0.2	0.5[g]	17.3	0.5	0.60
Bear*season*diel	4.9	10	0.5	0.3[c]	4470.0	1.6	0.09	5.6	10	0.5	0.4[c]	4470.0	1.2	0.29

a. 0.978 MS (Season * Bear number) + 0.834 MS (Diel * Bear number) – 0.834 MS (Season * Diel * Bear number + 0.022 MS (Error)
b. 0.719 MS (Season * Bear number) + 0.281 MS (Error)
c. MS (Error)
d. 0.727 MS (Diel * Bear number) + 0.273 MS (Error)
e. 0.852 MS (Season * Diel * Bear number) + 0.148 MS (Error)
f. 1.000 MS (Season * Diel * Bear number) – 0.000 MS (Error)
g. 0.727 MS (Season * Diel * Bear number) + 0.273 MS (Error)

Average Proportion of Crossings of Different Road Types by Bears. For 6 bears during 2 seasons, the average proportion of movements that crossed an open road was 0.08 (CI = 0.07, 0.09) during summer, and decreased to 0.03 (CI = 0.01, 0.07) during the fall hunt (Fig. 5). After the effects of elevation were removed, the proportion of movements that crossed open roads differed among seasons (p = 0.07, Table 4), but not among diel periods (p = 0.42). Elevation explained most of the variation (Table 4), and the slope coefficient for elevation was –0.008. The proportion of movements that crossed restricted roads did not differ among seasons (p = 0.75, Table 4) or diel periods (p = 0.99). In addition, the direction of seasonal effects differed between open and restricted roads (Fig. 5), suggesting that bears responded differently to open and restricted roads.

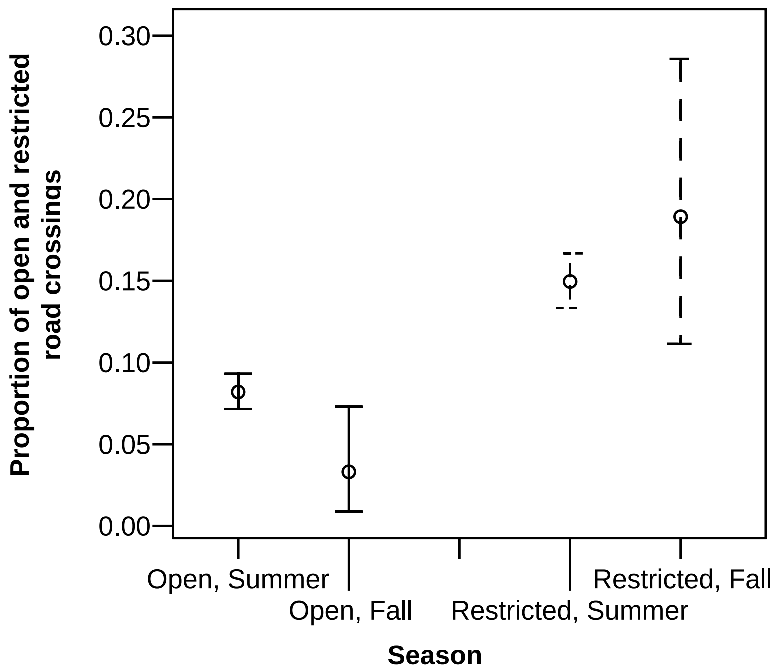


Fig. 5. Averages and 95% confidence intervals for the proportion of movements by bears that crossed open and restricted roads between summer and fall hunt ("fall") seasons (*n* = 6). Swan Valley, Montana. 2003-04.

Table 4. Proportion of movements that crossed open and restricted roads as a function of season, diel period ("Diel"), individual bear ("Bear number"), and interactions, with elevation as a covariate. Error terms were calculated from SPSS default as described in footnotes. Swan Valley, Montana. 2003-04.

	Open roads							Restricted roads						
Effect	SS	df	Hypothesis MS	Error MS	Error df	F	p	SS	df	Hypothesis MS	Error MS	Error df	F	p
Bear Number	6004.8	5	3200.9	839.0[a]	4.5	3.8	0.10	113014.2	5	22602.8	9888.0[a]	5.0	2.2	0.19
Season	3027.0	1	3027.0	742.5[b]	12.8	4.0	0.07	658.5	1	658.5	5687.2[b]	5.7	0.1	0.75
Elevation	3303.6	1	3303.6	588.7[c]	3277.0	5.6	0.02	47183.7	1	47183.7	786.1[c]	3277.0	60.0	<0.01
Diel	668.1	2	334.0	387.0[d]	160.8	0.8	0.42	13.3	2	6.6	599.8[d]	80.7	0.0	0.99
Bear*season	4404.5	5	880.9	274.3[e]	18.2	3.2	0.03	50474.1	5	10094.8	500.7[e]	15.2	20.1	0.00
Bear*diel	1887.4	10	188.7	231.1[f]	10.0	0.8	0.62	4165.8	10	416.5	461.5[f]	10.0	0.9	0.56
Season*diel	296.1	2	148.0	408.3[g]	120.3	0.3	0.70	95.9	2	47.9	622.4[g]	70.8	0.0	0.93
Bear*season*diel	2312.2	10	231.2	588.77[c]	3277.0	0.3	0.95	4615.7	10	461.5	786.1[c]	3277.0	0.5	0.83

a. 0.982 MS (Season * Bear number) + 0.863 MS (Diel * Bear number) – 0.863 MS (Season * Diel * Bear number) + 0.018 MS (Error)
b. 0.527 MS (Season * Bear number) + 0.473 MS (Error)
c. MS (Error)
d. 0.504 MS (Diel * Bear number) + 0.496 MS (Error)
e. 0.897 MS (Season * Diel * Bear number) + 0.121 MS (Error)
f. 1.000 MS (Season * Diel * Bear number) – 0.000 MS (Error)
g. 0.505 MS (Season * Diel * Bear number) + 0.495 MS (Error)

DISCUSSION

Once the effects of elevation were accounted for, bear distribution proximate to roads in the Swan Valley changed significantly between hunting and nonhunting seasons. Specifically, habitat use by bears proximate to open roads decreased from summer to fall hunt (Fig. 2, Fig. 4, and Fig. 5), suggesting avoidance of open roads by adult male black bears. Bears reduced their use of the roaded area in the fall hunt by over two-thirds, relative to summer (Fig. 2). In addition, it is also unlikely that bears living inside a roaded area will be near open roads during the fall hunt season (Fig. 4 and Fig. 5). Although other possible explanations exist, bears could be mitigating their vulnerability to hunting by avoiding open roads during fall hunt when shooting is legal.

Diel period was a significant factor in my large scale analysis (Table 2), although confidence intervals around each diel period were large (Fig. 3). The time bears spent in a roaded area changed significantly among diel periods. Bears spent the most time near roads during the day, less time near roads in crepuscular times, and the least time near roads at night. Numerous mechanisms could explain this pattern, but it is inconsistent with the idea that bears move away from the roaded area to avoid hunters because legal shooting hours occur only during day.

Response to Open versus Restricted Roads

Previous research shows an effect of roads with higher traffic volume on bear behavior. Brody and Pelton (1989) found that black bears rarely crossed interstate highways and crossed low-use roads more often. In northwest Montana, Kasworm et al. (1990) found that black bears avoided habitat within 274 m of open roads. In 2004, McCoy showed that Montana black bears crossed open roads more often during times of lower traffic volume. Beringer et al. (1990) reported that black bears avoided roads with higher traffic volume (>10000 vehicles/day) as the density of these roads increased. Although the Swan Valley had drastically lower traffic volumes, I assessed whether bears in my study area displayed similar behaviors relative to open and restricted roads. This study neither gives evidence for nor refutes the theory that seasonal responses differ between road types because the effects of season are non-significant for restricted roads.

The response of adult male black bears to open road density appeared to differ from responses to restricted road density. Although both road type densities were lower in the fall, the effect of season on open road density was larger than the effect on restricted road density (Fig. 4). One potential cause of the weaker effect of season for restricted roads can be observed in the interaction of season and individual. Average restricted road density for 2 individual bears *increased* from summer to fall hunt, which could be dominating the main effect and could account for the low significance of season for restricted roads. If this represents a change in response by bears to restricted roads (relative to open roads), this result makes sense given the relatively high volumes of traffic on open roads in the fall in the Swan Valley. Especially in areas of higher road density, traffic volume along these roads is high in the fall, increasing the likelihood that a bear in this study area would encounter a vehicle during peak hunting times.

Adult male black bears appeared to avoid crossing open roads at times when they were most vulnerable; the average proportion of open road crossings decreased by half from summer to fall hunt season (Fig. 5). In contrast, there was no significant difference in the proportion of crossings of restricted roads between summer and fall hunt seasons. Although the direction of the effects did change from open to restricted roads (suggesting that the effects of season do change for restricted roads), the effect of season was non-significant for restricted roads. The interaction of season and individual shows that one bear in particular used restricted roads in a manner opposite that of the majority of bears (showing an increase in restricted road crossings from summer to fall hunt); this may help explain the weaker effect of season for restricted roads.

Possible Causes for Seasonal Differences

Factors other than vehicular traffic affect habitat use by black bears. McIlroy (1972), Rogers (1987), and Rossell and Litvaitis (1994) suggested that factors such as intraspecific competition, darkness, weather, land-use practices, or changing human pressures may also alter habitat use. More specifically, other studies have shown that elevational changes by bears across seasons could be the result of additional factors including availability of particular food items (Jonkel and Cowan 1971, Servheen 1983, Rogers 1987, McLellan and Hovey 1995). Amstrup and Beecham (1976) found a significant correlation between black bear movements and availability of food. Early in the year, bears were most active at lower and middle elevations, following budding plants up in elevation by late May and June. These bears typically stayed in mid- to higher elevations, where berries were ripening, from mid-summer until they denned. Because the elevational changes by bears in the 1976 study corresponded to changes in food sources, it is most likely that these black bears were responding more to food availability than to increasing hunting pressures during fall hunt.

McIlroy (1972) and Rogers (1987) found a possible effect of hunting on the distribution of black bears, particularly for adult males. McIlroy (1972) found that as hunting pressure in Alaska shifted to areas farther from humans, the percent of adult male black bears in the harvest increased. Even in areas of good habitat, the relative density of adult male black bears was much lower in a heavily hunted area relative to an area with less hunting pressure. The observed changes in bear distribution may be a consequence of adult males avoiding human development in general. However, these adult males may also be responding to increasing harvest pressures by moving away from heavily hunted areas; in Montana, heavily hunted areas are typically near roads.

Based upon my observations in the Swan Valley, food availability and hunter avoidance are the most likely factors that explain why adult male black bears change habitat use between seasons. A small sample of bears (two of six) in my study had location data that included spring hunt season. Although this small sample may not accurately reflect the average bear response to roads, the pattern of habitat use displayed by these 2 bears gives greater support for the hypothesis that adult males in my study are responding to hunting than for the belief that bears change use of habitat near roads based upon food availability. I would expect that, if adult male bears altered habitat use between seasons to avoid hunters, habitat use will be approximately equal during both hunting seasons, but less than habitat use during summer (e.g., if bears altered distribution between seasons to avoid hunters, I would expect the average proportion of road crossings to be approximately equal during both hunting seasons, and less than the proportion of road crossings during summer).

Although I did perform identical ANCOVAs on these 2 bears, I did not include this sample in the overall analyses because of the particularly small sample size. I used a mixed model ANCOVA and evaluated the effect of season, diel period, and factor interactions on road density and the proportion of road crossings relative to these 2 bears' locations. I also determined the mean and upper and lower confidence intervals of these road metrics. Open road density proximate to bears increased from spring hunt (0.40 km/km^2, 95% CI = 0.28, 0.53) to summer (0.60 km/km^2, 95% CI = 0.55, 0.65), and decreased from summer to fall hunt (0.12 km/km^2, 95% CI = 0.01, 0.24). Open road density differed among seasons (ANCOVA, $F = 1.9$, hypothesis df = 2, error df = 2.0, $p = 0.14$). The average proportion of open road crossings for 2 bears was 0.04 (95% CI = 0.01, 0.08) during spring hunt, increased to 0.06 during the summer (95% CI = 0.05, 0.07), and fell to 0.002 (95% CI = 0.001, 0.016) during fall hunt. For open roads and 2 bears, the proportion of crossings differed marginally among seasons (ANCOVA, $F = 1.5$, hypothesis df = 2, error df = 2.1, $p = 0.16$). For both metrics, this rise-and-fall pattern of habitat use from spring to summer to fall seasons reflects what I expected if bears were responding more to hunter avoidance than to food availability. However, it is difficult to fully explain why bears change habitat use seasonally because many causal variables are also highly correlated.

In my study, season had an effect on bear responses to roads in the "highly roaded environment" (R. Mace pers. comm.) of the Swan Valley. However, the effects that we see could be confounded by other variables, such as elevation, that are correlated with roads. I accounted for this by using ANCOVA, and treating elevation as my covariate. My study showed a significant effect of season after elevational effects were removed, even though elevation explained the majority of the variance (Tables #3 and 4).

In my study, elevation was a significant predictor of responses to roads by bears (Tables #2, 3 and 4). I used the slope coefficient of elevation to determine the magnitude and direction of elevational effects. In general, bears in my study were less likely to be in an area with high road density. The slope coefficient for ANCOVA #1 was high and negative, indicating an inverse probability. Specifically, the probability that a bear was in the roaded area differed strongly depending upon whether the bear was at an elevation with roads or an elevation without roads (e.g., a bear at high elevations was much more likely to be outside the roaded area.) This is not surprising because elevations in the roaded area are lower and therefore contain more roads. I expected that road density should decrease with increasing elevation because there are fewer roads at higher elevations. The slope coefficients for ANCOVAs #2 and 3 were both low and negative. The negative value indicates an inverse relationship between roads and elevation; there are fewer roads at higher elevations. However, the magnitudes of the slope coefficients are lower than that of ANCOVA #1, showing that the difference in elevation between seasons or diel periods is less for these two metrics. This is what I would expect, given that analyses were restricted to the roaded area where elevations do not change greatly. Especially in the roaded area, elevation and roads were confounded, making it difficult to tease apart individual effects. Thus, interpretations of bear avoidance of roads should be treated with caution, as bear responses to roads may also be a response to elevation.

Mace et al. (unpubl. data) observed an increase in the proportion of subadult male bears in annual MFWP regional harvests as road density increased (e.g. valley bottoms). Some researchers (Montana Fish, Wildl. & Parks, unpubl. data; Rogers 1987) have suggested that this may reflect a population composition skewed towards subadult males in areas with high road density. I found no literature giving evidence for this pattern; however, my research could contribute to this knowledge base. My research shows that adult males appear to avoid roads during hunting season, which suggests that space is left vacant for subadults to enter these areas, and could help explain why subadult harvest is high in highly roaded environments in Montana (MFWP, unpubl. data).

Management Implications

My results are limited by sample size. However, small sample sizes such as these are common for wide-ranging, low-density, and solitary animals like bears (Grenfell and Brody 1983, Servheen 1983, Roth and Huber 1986, Mace et al. 1996, Waller and Mace 1997, Chi and Gilbert 1999, McLellan and Hovey 2000). Further research into black bear use of roaded areas and hunting vulnerability is warranted. An increase of sample size, especially during spring hunt, and inclusion of females and different age classes, would be beneficial. In particular, with new technological capabilities, I recommend that anyone initiating a similar study consider maintaining a larger sample size through the winter to obtain more data including spring hunt. In addition, future studies could include additional road metrics, such as distance to roads, relative to hunting and nonhunting times. A comparative study that involved monitoring bears in wilderness areas and roaded areas would also improve our knowledge.

This study illustrates the importance of season in determining how bears use roads, on both large and small scales, by using familiar methods in an innovative way. Specifically, adult male black bears in a roaded area are unlikely to be near roads during the fall hunt season, which reduces their vulnerability to the hunt. If we assume bears are limited by habitat, roads reduce habitat available to adult male black bears during the hunting season. In addition, restricting roads may not mitigate these effects, because we do not know for certain whether some other, confounding factor(s) alters the effects of season for restricted roads. However, we do not know how much of an effect matters to adult male black bears or whether habitat does in fact limit adult male black bears.

Even if the effects of road restriction are ambiguous, my study's results regarding seasonal effects are robust. In particular, the pattern of habitat use between seasons is consistent across both large and smaller scales; bears are unlikely to be near roads during hunting seasons. These results are not good news for trophy black bear hunters looking for an effortless harvest near roads; nor can we expect that building more roads into habitat that is currently unroaded will lead to more trophy black bears. Game managers can use these results to help guide effective conservation and hunting management, managing the timing of when roads are open or restricted to help produce and maintain a healthy distribution of black bear harvest.

APPENDIX

Background Analyses

Many of this study's adult male black bears used areas outside of the roaded area. In this Appendix, I present the home ranges of each bear to illustrate each bears' movements, both inside and outside the roaded area. This Appendix also includes an evaluation of how habitat use near roads for each collared adult male black bear differed from "average" (random) road use. MFWP managers requested that I provide them with a simple description of: 1) How road densities near collared bears differed from average road densities and 2) How the proportion of movements by collared adult male black bears that crossed a road differed from average road crossings.

Methods

Annual and Seasonal Home Ranges. Home range sizes for studies of selection are most accurate if calculated using the kernel home range method (Worton 1987, Belant and Follman 2002). The majority of research describing distribution employs the more general Minimum Convex Polygon (MCP, Mohr 1947) method (Worton 1987, Mauritzen et al. 2001). Whereas MCP methods estimate areas by connecting outer locations, kernel methods estimate home range areas using probability densities. I see an advantage of displaying home range sizes using both methods as this allows a comparison between probabilities of use (kernel) and a sum of outer locations (MCP).

The shapes of kernel probability densities are defined in large part by the smoothing parameter, or 'h', value. An advantage of the Animal Movement extension in ArcView is that its ad hoc calculations of h are very close to the Least Squares Cross Validation methods based on Silverman (1986) but do not require lengthy processing times.

I used the Animal Movement extension (SA v 2.04 beta, USGS-BRD, Alaska Science Center Biological Office, Glacier Bay Field Station, USA) to calculate annual home ranges of each bear using both MCP (Fig. A1) and fixed kernel (Worton 1989, Fig. A2) home range methods. I calculated annual home ranges using locations during all seasons available. When calculating annual home ranges, I censored location data occurring after 31 July for one bear (individual #299). The collar of bear #299 dropped prematurely and at an unknown time, so location data of this individual were truncated at a date on which points became centralized to an area of approximately 3 kilometers (which approximated the collar's release date). To calculate seasonal home ranges for each bear, I used bears whose locations occurred in more than one season and selected all locations within each season using both the MCP and kernel home range methods. Kernel home range sizes were established using the 95% kernel contour level and MCP ranges at 100%.

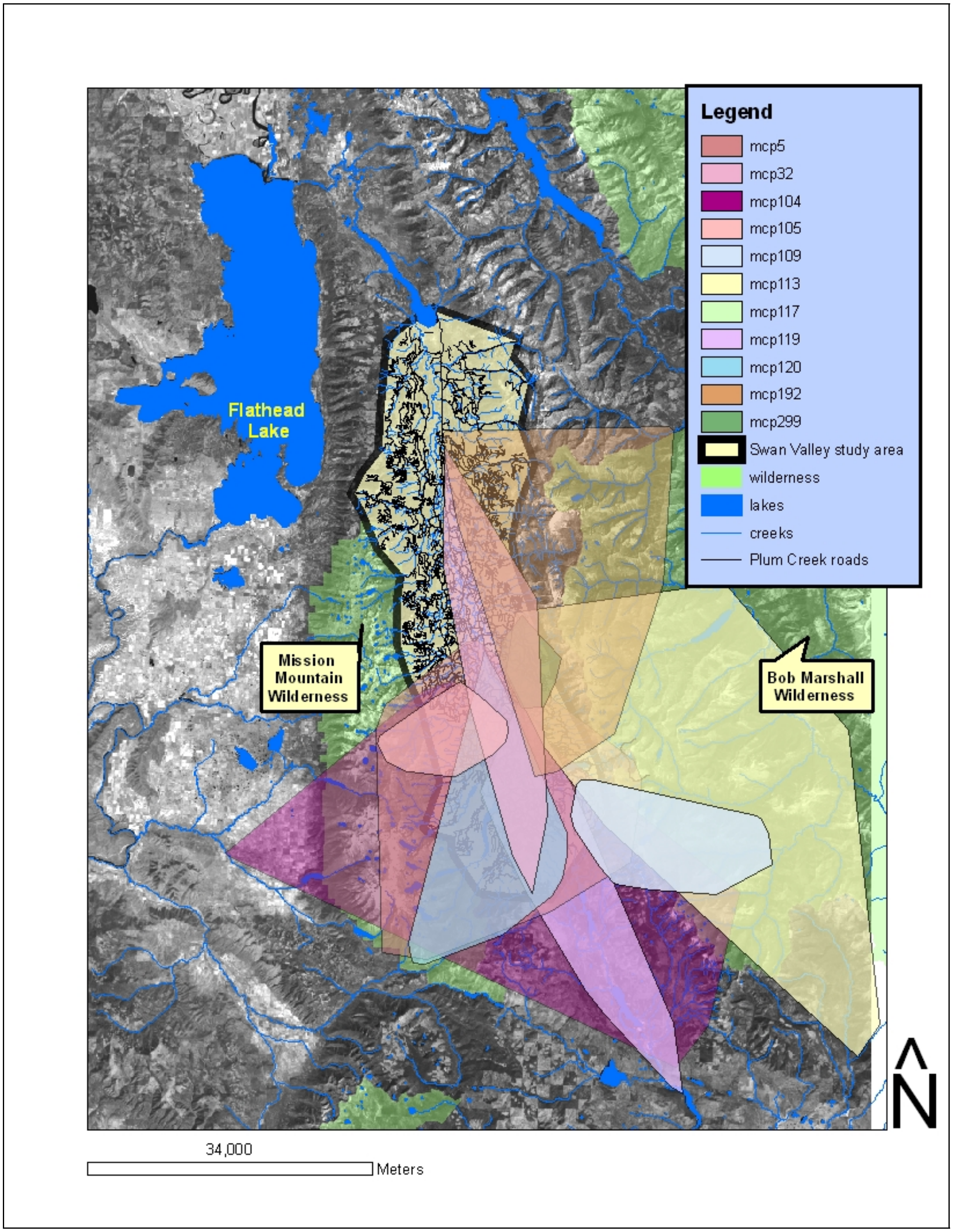


Fig. A1. Annual adult male black bear home ranges, using Minimum Convex Polygon methods. Swan Valley. 2003-04.

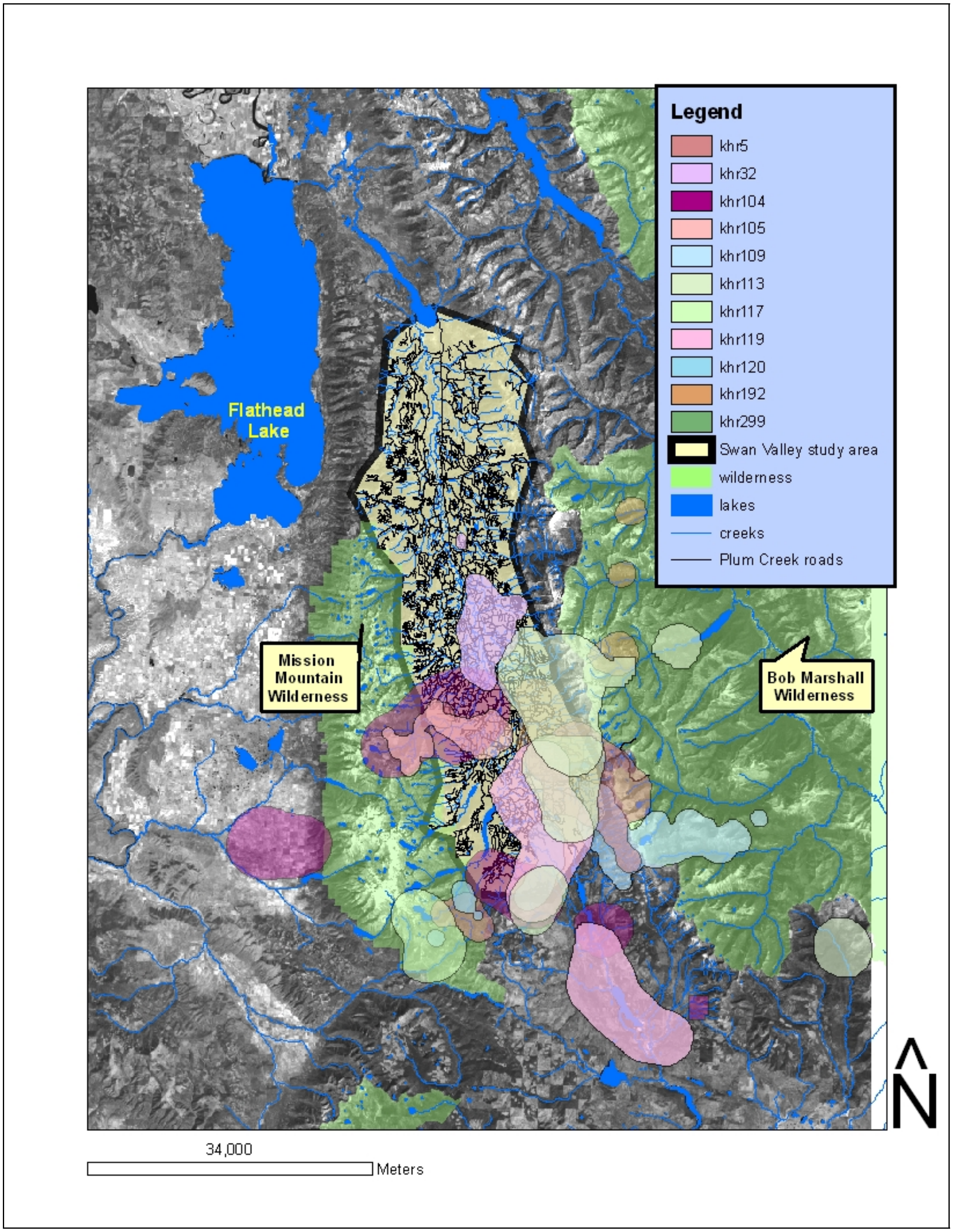


Fig. A2. Annual adult male black bear home ranges, using kernel (95% contour) methods. Swan Valley. 2003-04.

Road Densities: Used versus Average "Random". I used the average number of fixes in the roaded area for all 6 bears (n = 799) to define the average number of locations, then used Animal Movement extension to generate this number of random locations inside the roaded area. I created a circular buffer around each location, with a diameter equal to the average total movement length in a 2 h period of *all* bears. For each buffered location, I calculated the density of open and restricted roads within the buffers, and ln-transformed the data to normalize them.

Road Crossings: Used versus Average "Random". I found the average number of successive locations of all bears (n = 552) and used this as the number of average locations. I generated this number of random points inside the southern half of the study area and connected the points to form movement paths. I buffered all roads by 100 m, and used Alternate Animal Movement Routes extension (Alternate Animal Movement Routes v. 2.1, Jeff Jenness, Jenness Enterprises, USA) to determine the proportion of movements that crossed a road. I evaluated the proportion of movements that crossed open roads and repeated the analysis for restricted roads. As these proportional data were not normally distributed, I transformed them using the arcsine-squareroot transformation.

Results

Annual Home Ranges. The average annual MCP home range size for adult male black bears was 160.4 km^2 (SD = 101.9 km^2, Table A1) and average annual kernel home range size was 61.7 km^2 (SD = 34.5 km^2). Annual MCP home range sizes varied between 22.2 km^2 and 315.7 km^2, and kernel home ranges varied between 21.2 km^2 and 103.9 km^2.

Table A1. Minimum Convex Polygon (MCP) and 95% kernel (k) home range sizes for each adult male GPS-collared black bear (n = 11). Swan Valley, Montana. 2003-04.

Black bear number	Sample size[1]	MCP home range area (km^2)	95% kernel home range area (km^2), h[2]	
5	1476	256.8	85.6	932.1
32	630	315.7	76.5	1131.7
104	1285	273.1	98.6	1429.5
105	1179	73.9	31.9	480.2
109	997	22.2	24.3	447.7
113	1034	89.1	65.1	730.9
117	1054	118.4	103.9	1149.0
119	907	126.9	88.3	875.9
120	1016	178.0	27.7	643.9
192	1569	259.5	56.1	958.4
299	651	51.1	21.2	295.8
	Mean	160.4	61.7	
	SD	101.9	34.5	

[1] Sample sizes are equivalent to the number of fixes used to determine each bear's home range.
[2] Ad hoc smoothing parameter (h) values of each kernel home range area are given after home range value.

Seasonal Home Ranges. Seasonal home range sizes were smallest during the spring hunt season, for both home range methods (Table A2). The average home range size during spring hunt using MCP was 17.0 km^2 (SD = 3.1) and equaled 17.2 km^2 (SD = 6.9) using kernel methods. Seasonal home range averages were largest during the summer season; MCP summer home ranges averaged 179.3 km^2 (SD = 97.8) using MCP and 59.5 km^2 (SD = 25.1) using kernel methods. Home ranges during fall hunt were smaller, on average, than either spring or summer. Using MCP methods, fall hunt season home ranges averaged 25.7 km^2 (SD = 19.7) and averaged 41.0 km^2 (SD = 49.6) using the kernel method.

Table A2. Seasonal home range sizes (km^2) of adult male black bears occurring in more than one season (spring hunt, summer, and/or fall hunt). Swan Valley, Montana. 2003-04.

	Spring hunt		Summer		Fall hunt	
Bear number	MCP[1]	k[2]	MCP[1]	k[2]	MCP[1]	k[2]
5	19.2, 61	22.0 (642.2)	255.9, 732	92.6 (992.3)	3.6, 42	1.8 (305.0)
32	14.8, 227	12.3 (375.5)	304.4, 605	73.8 (1116.2)	60.9, 25	135.7(1852.2)
105	NA	NA	73.5, 802	31.6 (480.9)	23.3, 32	24.3 (691.3)
113	NA	NA	89.0, 411	63.8 (743.4)	29.6, 103	45.8 (942.9)
120	NA	NA	117.5, 754	27.7 (643.4)	25.1, 28	35.6 (847.0)
192	NA	NA	235.6, 819	67.2 (1176.8)	11.9, 154	2.7 (318.4)
Mean	17.0	17.2	179.3	59.5	25.7	41.0
SD	3.1	6.9	97.8	25.1	19.7	49.6
Minimum	14.8	12.3	73.5	27.7	3.6	1.8
Maximum	19.2	22.0	304.4	92.6	60.9	135.7

[1] Minimum Convex Polygon (MCP) sizes are listed at 100%, with location sample sizes given after comma.
[2] Kernel home range sizes are given at the 95% contour level, with ad hoc ‘h’ values shown in parentheses.

Road Densities: Used versus Average. For 6 bears, average open road densities were greater than open road averages for random locations (Fig. A3). The average restricted road density for random locations was less than the restricted road averages for all bears except one (black bear #105).

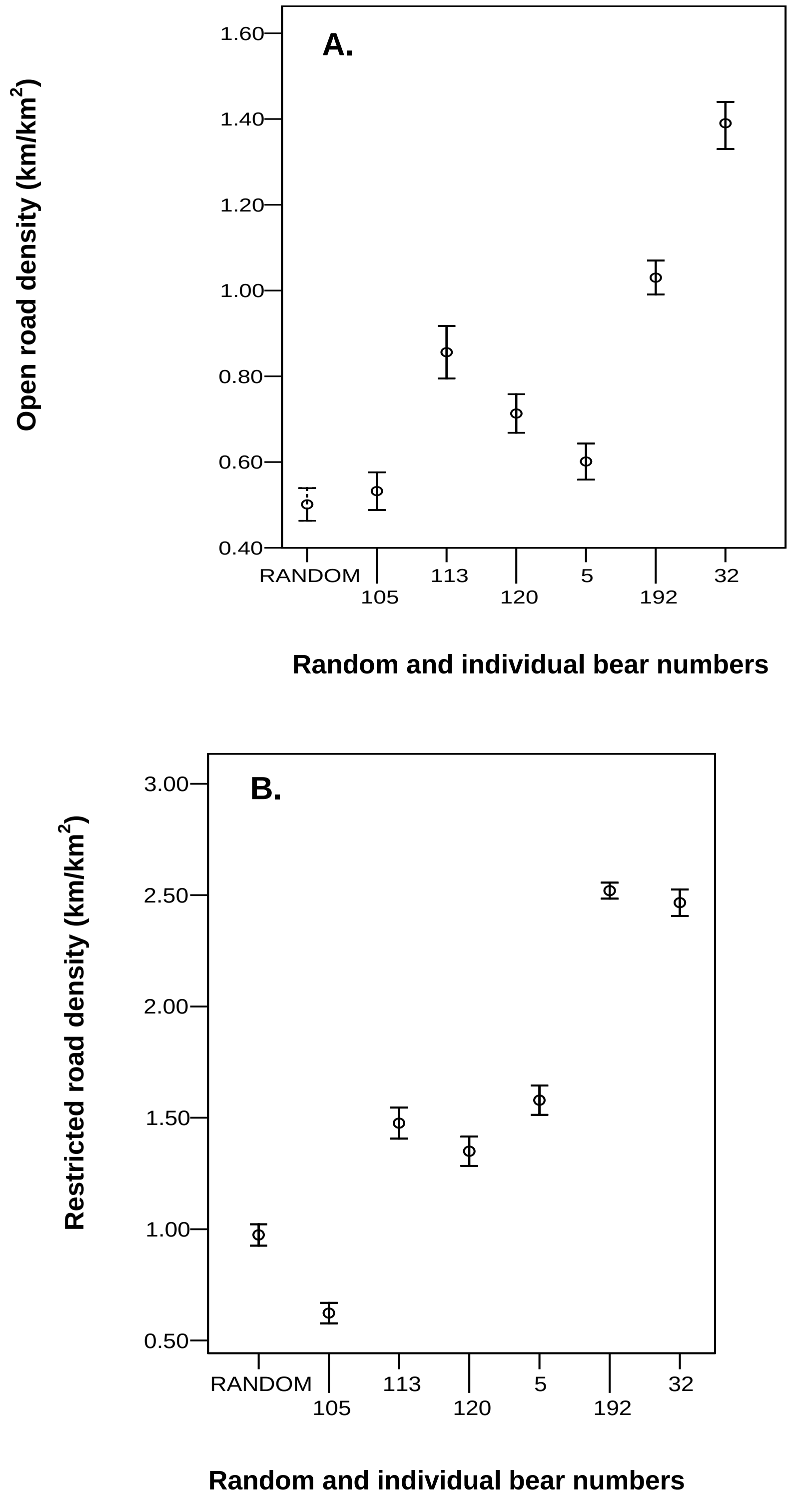
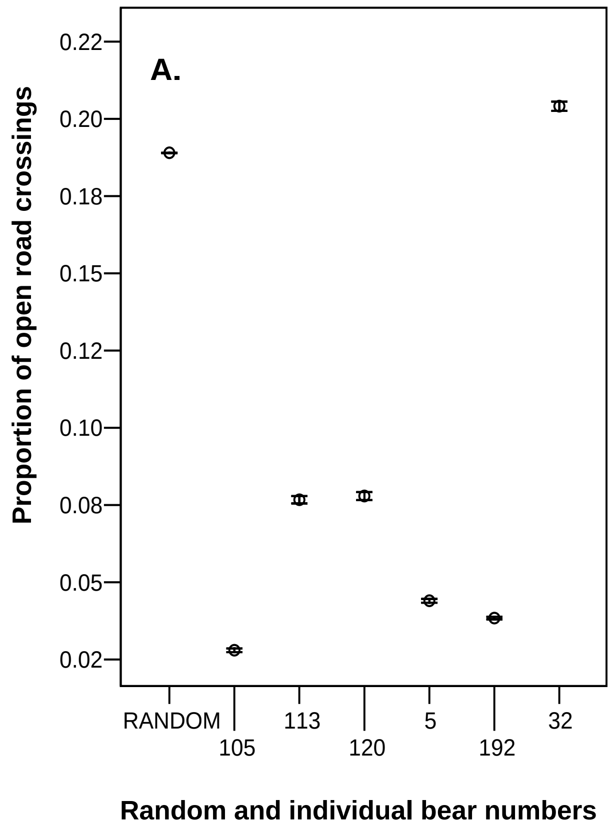


Fig. A3. Averages and 95% confidence intervals for open (A) and restricted (B) road densities for random points, compared to average road densities and 95% confidence intervals proximate to collared adult male black bears (*n* = 6). Swan Valley, Montana. 2003-04.

Road Crossings: Used versus Average. The average proportion of open road crossings for random movements was higher than the average proportion of open road crossings for all but one black bear (black bear #32, Fig. A4). The average proportion of restricted road crossings for random movements was higher than the average restricted road crossing averages for all bears except one (black bear #192).



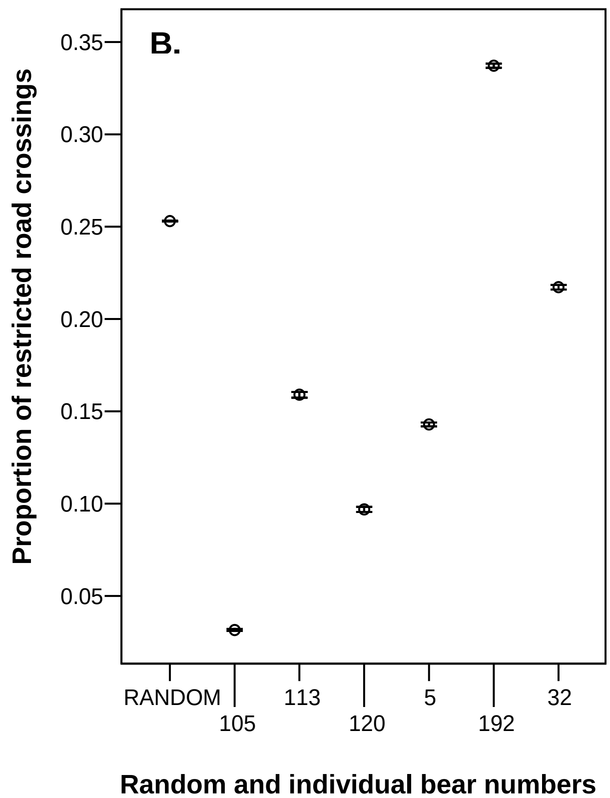


Fig. A4. Averages and 95% confidence intervals for the proportion of open (A) and restricted (B) road crossings for random points, compared to the average proportion of road crossings and 95% CI's proximate to collared adult male black bears (*n* = 6). Swan Valley, Montana. 2003-04.

DISCUSSION

Home Range Characteristics. Home range size is positively correlated with sample size. Using either the kernel or MCP method, adult male black bears that were monitored for a shorter time period had relatively smaller annual *and* seasonal home range sizes. This may explain larger summer and smaller spring home ranges relative to other seasonal home range sizes.

Used versus Average. Average road density of both open and restricted roads proximate to most bear points was higher than average road density proximate to random points (Fig. A3). The reason for this greater-than-expected density of both road types is unclear, but could have to do with small sample sizes or confounding factors.

The majority of bears appeared to cross fewer open and restricted roads than were expected (Fig A4). It is possible that a bear crossing an open road during hunt seasons could risk being observed directly by a hunter hunting from a road or risk their track being crossed by a hunter; the hunter could then track the bear to kill it. My research focuses on adult males; as the oldest age class, I assume that the more each individual reduces the proportion of movements that cross open roads the greater their probability of survival to maturity.

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